**One of the greatest gifts our modern human technologies have brought us is the ability to maintain safe comfortable temperatures in our living and working spaces without the need to find blocks of ice to cool down or firewood to keep warm.**

**But of course, we all now know the environmental and climate costs of those technologies, most of which use fossil fuels in one form or another, either directly for heating, or indirectly via national electricity grids.**

**According to the International Energy Agency, the use of air conditioners and electric cooling fans accounts for nearly twenty percent of the total electricity used in buildings around the world. And that number is much higher if you include mobile cooling in private vehicles and on public transport, plus industrial and commercial refrigeration for keeping food fresh and for chilling critical products like pharmaceuticals.**

**There’s something like three point six billion cooling appliances in use today all over the world, and that number is going up by about ten devices every second.**

**And as we move rapidly way from gas and oil and towards electric heat pumps for space heating, even greater demand will be placed on our grids.**

**These things draw a lot of energy, and many of them use hydrofluorocarbons or HFCs as a refrigerant gas. HFCs aren’t quite as disastrous as the CFCs that were banned by the Montreal Protocol thirty years ago. They don’t wreck the Ozone layer, but they’re still extremely potent greenhouse gases, often hundreds of times more powerful than carbon dioxide.**

**So, the race is on to find better solutions to the rapidly growing challenge of heating and cooling, with better energy efficiency and without potentially harmful emissions. And now a British company looks like they’ve achieved precisely that, with an elegantly simple system inspired by this thing – the Stirling Engine.**

**Hello and welcome to Just Have a Think,**

**Stirling Engines are an example of an external combustion engine. The energy that drives them comes from outside the closed system, as opposed to an internal combustion engine where the fuel is burnt inside the combustion chamber.**

**So how does it work?**

**Well, in this little model version we’ve got two thin metal plates at the top and the bottom. And we’ve got this little block of foam sitting inside the enclosed space between the plates. If I was to put the model onto something hot, like a cup of coffee, the heat energy from the coffee would warm up the bottom plate. That would make the air inside the chamber expand, and as it expanded it would push this little piston upwards. The piston is attached to the wheel via this rod. So as the piston goes up, the wheel starts to turn. But the wheel is also attached to the foam block, so as it turns, it pushes the block downwards. That forces the air to flow past the block and come into contact with the top plate, which is cooler. The cooling air contracts, pulling the piston back down, which turns the wheel a little bit more. And as the wheel continues to turn it pulls the foam block back up, forcing the air back down to the hot side, and the whole cycle starts again.**

**As long as there’s a temperature difference between the top plate and the bottom plate then the engine will keep running. In fact, you could put this thing on top of a block of ice and it would still work, albeit with the wheel turning in the opposite direction, because the top plate would then be warmer than the bottom plate.**

**The greater the temperature difference between the two plates, the more efficiently the system will run, and conversely, if there’s no temperature difference at all, the whole thing grinds to a halt.**

**But Stirling’s invention is one of the few cycles that can be run in reverse to effectively make it a heat pump instead of a heat engine. If I use the energy in my arm to manually turn the wheel, or in a more sophisticated version, if I attached a drive shaft to it, powered by a little electric motor, then the expansion and compression of the air would make one plate hot and the other plate cold. And if that system was scaled up then you could theoretically draw the heat or the cold off from one plate of the other depending on whether you wanted to heat a space or cool a space.**

**Sounds simple right? So why don’t we run all our heaters and coolers that way, instead of using air conditioning units that contain all those horrible hydrofluorocarbon refrigerant fluids?**

**Well, it all has to do with something called the Carnot Cycle and whether a gas is expanding isothermally or adiabatically.**

**I know… ‘science jargon’... I know.**

**The full explanation of the Carnot Cycle is beyond the scope of this video but suffice to say it represents the theoretical maximum efficiency of a heat pump or a heat engine.**

**Isothermal just means constant temperature. So, if a gas is expanded or compressed isothermally, it stays at the same temperature all the time.**

**It’s much more normal though for a gas to be compressed or expanded adiabatically, which means it’s temperature increases or decreases as it’s compressed or expanded.**

**To achieve the ideal efficiency of the Carnot Cycle, a Stirling Heat Pump would have to run a hundred percent Isothermally, so that the gas was able to lose all it’s heat energy as it was being compressed, and draw in enough heat energy to stay at a constant temperature while it was being expanded.**

**That kind of energy exchange might be possible for the gas molecules right next to the outer wall of the chamber, but the molecules in the middle of the chamber are a very long way away, so to achieve a fully isothermal cycle you would have to run it extremely slowly to allow time for all those molecules to either give up or take in energy.**

**And that’s just not practical for any real-world application. You’d be waiting hours or days for your room to cool down or heat up.**

**So instead, air conditioners and refrigeration units around the world today use vapour compressor heat pump technology that’s been around for more than a hundred and sixty years and which relies on those nasty refrigerants with very high global warming potential or GWP. And they still only achieve about forty percent of the Carnot Cycle efficiency.**

**But now a new system has been created that takes the elegant simplicity of the Stirling Cycle and applies some good old engineering lateral thinking to the challenge of heat energy transfer to produce a working heat pump that can reach sixty percent of Carnot without using any gases with high GWP values.**

**The design is the brainchild of hydraulic engineer Michael Crowley and is being developed by his company, Fluid Mechanics, who are specialists in the design, analysis and modelling of hydraulic systems.**

**Several prototypes have been built and tested since the beginning of the project back in 2015. All of them are based on the principle of pistons and cylinders to achieve a similar effect to this version of a Stirling Engine, known as an Alpha Type.**

**Essentially, the gas in the expansion cylinder is heated externally and the gas in the compression cylinder is cooled externally. That sets up the temperature differential needed to make the pistons move, to rotate the drive shaft.**

**Just like in my little model version, the gas is able to flow between the two cylinders, which it does via this channel, known as a regenerative heat exchanger.**

**The heat pump developed by Fluid Mechanics also has two cylinders, just like the Alpha-type Stirling engine. In fact, the working model will have another pair of cylinders at the back to optimise the mechanical balance of the system.**

**Each set of two pistons are attached to each other via something called a Ross Yoke, which is a clever piece of existing technology designed to keep them out of phase with each other by about a hundred and twenty degrees, again very similar to the Alpha Type Stirling Engine.**

**The gas is expanding and compressing, and we’ve also got a regenerative heat exchanger moving the gas between the cylinders. So far so ‘samey’…**

**But remember the Fluid Mechanics system is set up to be a heat pump not a heat engine. That means the drive shaft is providing the input power to move the pistons up and down rather than vice versa.**

**So now we’ve got to find a way removing the heat from one cylinder and the cold from the other. The Fluid Mechanics system achieves that in two ways. Firstly, by using helium as the working fluid rather than ambient air, and secondly by adding a series of thin metal fins to the bottom of each piston.**

**Helium molecules are much smaller than air molecules, so they can move much faster. That means they can transport energy more quickly too. In fact, the thermal conductivity of helium is ten times greater than air. And according to Michael, you could just as effectively use hydrogen gas for exactly the same reasons.**

**The helium gas is held between the metal fins at the base of each piston. The distance between the fins is just two millimetres, so the average distance that any helium molecule has to travel to get to a fin is just nought point five millimetres.**

**And that means heat transfer out of, or into, the gas is extremely rapid indeed.**

**As each piston completes a cycle, the fins are plunged into a sump of silicon oil where they’re quenched. Depending on which side of the system the quenching happens, the oil is either heated up a bit or cooled down a bit. A circulating pump moves the oil constantly around an external circuit via a heat exchanger where it heats up water on the hot side and cools it down on the cold side.**

**To measure the basic system efficiency, Fluid Dynamics created this test rig, which looks a bit like something out of Back to the Future, but is in fact a very carefully calibrated scientific instrument.**

**Based on measurements of the pressures inside the chambers, the rig demonstrated that it was achieving ninety five percent isothermal efficiency. Very close to the theoretical maximum of the Carnot Cycle, with an overall ‘real world’ working efficiency of sixty percent once all system losses are accounted for.**

**The performance of all heat pumps improves as the temperature difference gets smaller. It’s a function known as the coefficient of performance or COP. So, if the ambient temperature is nineteen degrees and you want, say, your room or your car to be at twenty-one, then your system will have no trouble at all. But if it’s forty-five degrees Celsius outside and you’re trying to get eighteen degrees inside then the COP number will drop significantly. That’s the same for all heat pump systems, and the Fluid Mechanics design is no different. Nevertheless, their current two point seven kilowatt prototype is capable of generating a temperature difference of sixty degrees Celsius between hot and cold. The next development model will be a ten kilowatt unit with improved technology that Fluid Mechanics expect to reach temperature differences of about eighty degrees Celsius.**

**That could happily run an industrial freezer in a building where the external temperature was over thirty degrees Celsius, or if it was configured as a heating device, it could provide hot water at about sixty degrees Celsius when the external temperature was less than minus ten.**

**In principle, the design can be scaled all the way up to on megawatt of cooling capacity. Something that has attracted interest and funding from the Navy, who currently cool their ships with air conditioning units that leak refrigerant gases all the time, making it extremely difficult for them to achieve their emissions reductions targets as part of the Paris agreement.**

**So, there it is. A system that achieves a 30% energy saving versus the current technology with absolutely no high GWP refrigerant gases, and which by the way also operates much more quietly than a traditional refrigeration unit.**

**And the potential applications are everywhere, from air conditioners in buildings to refrigeration units on lorries, and even cabin heaters in electric vehicles.**

**Fluid Mechanics reckon they’re about three years from full production capacity, but if they can successfully bring this innovation to market then it could potentially have a hugely beneficial impact on the energy requirements of our rapidly warming world.**

**If you’ve got feedback and views on this one, or if you work in the HVAC or refrigeration industry and you’ve got insight that you can share, then jump down to the comments section below, and leave your thoughts there.**

**That’s it for this week though.**

**Thanks as always to the amazing folks who support this channel via Patreon and help me keep the video content independent and ad free. And I must just give a quick shout out the folks who’ve joined since last time with pledges of ten dollars or more a month.**

**They are**

**Bill Urech**

**Phil Hall**

**Mike Palmer**

**Max Kroschel**

**Chuck Tyler**

**Bill O’Connor**

**Yan Chang**

**Andrew Keller**

**Lawrence Bottorff**

**Stanaforth Hopkins**

**Scott B.M**

**Scott Adams**

**Sebastien Sirois**

**Chris Nenov**

**and**

**Matthew York**

**And of course, a big thank you to everyone else who’s joined since last time too.**

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**As always, thanks very much for watching, have a great couple of weeks, and remember to Just Have a Think.  
See you next time.**